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Applying network analysis to assess coastal risk planning

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ABSTRACT

Adequate response to risks affecting coasts requires an integrated and coordinated multi-risk governance system, with ongoing evaluation of statutory planning documents and responsible stakeholders. Traditionally, such analyses have been carried out using mainly qualitative approaches. This paper adopts a more systemic and quantitative perspective on assessing planning systems and stakeholder relationships in connection with coastal risk. We apply network analysis to the Catalan coast (Northwestern Mediterranean Basin), paying special attention to the level of climate change integration in the planning system, as an aggravating factor of current risk dynamics. Our results demonstrate and quantify the complexity of Catalan coastal risk planning, which requires dealings with multi-level legal and administrative frameworks. Also highlighted is dissimilar management traditions according to risk type: the perspective on flooding risk is more unified and multi-risk focused, whereas coastal erosion (a significant issue for the Catalan coast) is managed more sectorially from a centralized administrative level. Climate change, moreover, is weakly accounted for in current statutory planning. We also acknowledge the relevance of using qualitative information as an important complement in interpreting results and making policy recommendations.

1. Introduction

Coasts are some of the most valuable ecosystems on Earth in terms of biodiversity and productivity but also as providers of ecosystem services that guarantee human development and well-being. The growing urbanization of coastal areas, combined with climate change, aggravate both risks and their damaging consequences. Risk management — a systemic and a complex issue (Renn, 2008) due to inherent uncertainties, multi-scale dynamics and many competing interests (Functowicz and Ravetz, 1992) — is particularly important for coastal areas in that many physical, environmental and socioeconomic components are simultaneously affected by natural and anthropogenic threats.

This situation requires an integrated and strategic approach to coastal management that has gained importance in Europe since 1999 (Ballinger et al., 2010). The European Union has committed to the implementation of a programme for Integrated Coastal Zone Management (ICZM) in order to deal with the complexity of coastal risks. ICZM is a process for harmonizing a range of policies and decision-making structures so as to facilitate concerted action aimed at achieving sustainability goals by taking into account the interconnectedness of biophysical and socioeconomic components of coastal systems (Reis et al., 2014). ICZM also highlights adaptation as one of the most promising principles for promoting the sustainability of coastal areas. This multidimensional approach, which is of relevance to different management areas, ranges from technical strategies to cope with climate change (such as options for "working with nature") to the design of appropriate governance systems.

Our interest lies in governance, given that institutional aspects — such as statutory planning and coordination between authorities — will enhance or limit ICZM effectiveness. From this perspective, risk governance requires an integrated, holistic, multi-risk planning approach which should incorporate all phases of risk management (prevention to emergency) and which should take into account participation by a wide range of stakeholders (Ribot, 2008) in an ongoing assessment process. Understanding governance systems, planning and stakeholder relationships in a risk management context is essential to improving the sustainability of coastal environments (Olsen, 2000). Our focus on networks is relevant, given that the number and variety of stakeholders, their relationships and their level of coordination and integration in natural resource management may foster or impede the implementation of more risk-adaptive management strategies (Bodin and Crona, 2009; Janssen et al., 2006).

The study of networks reflecting stakeholder complexities and how these can contribute to improving sustainability issues is championed by Eleanor Ostrom (2005, 2010), who has shown, for

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instance, how horizontal, multi-scale structures with interacting networks are very suitable for the management of natural resources. Moreover, diversified networks composed of different types of stakeholders encourage cooperation across different scales and political and physical boundaries (Peters and Pierce, 2004; Reed and Bruyneel, 2010). Collective learning and the development of expertise are both fostered when complex problems are dealt with and negotiated within this type of network, which reflects multiple perspectives on knowledge (Cundilla and Rodelab, 2012). Folke et al. (2005) have also shown how social networks can promote accessibility to, circulation and communication of different types of reliable information. Network analysis based on graph theory is a quite a novel approach, yet it seems particularly suited to dealing with power relationships and knowledge distribution in the management of natural resources, as demonstrated by several authors (Berkes et al., 2003; Adger et al., 2005; Bodin and Prell, 2011; Crona and Bodin, 2006; Crona and Parker, 2012; Franquesa and Budapest-Mengual, 2009; Roca et al., 2014). Network structures affect the ability of actors stakeholders to cooperate, share information and adapt their behaviour to new circumstances (Berardo et al., 2017).

Social network analysis has, to date, been little used in the field of coastal management (Roca et al., 2014), even though it is a powerful means for quantitatively measuring the number, types and intensity of interactions between social groups. Traditionally, the methodologies used for coastal management have been mainly qualitative and fragmented, based as they are on legal documents, grey literature and stakeholder-provided information and observations.

The purpose of the paper is to use network analysis as an integrative, systemic and quantitative approach to assessing relationships between coastal risk planning systems and stakeholders. The ultimate goal is to gain a deeper understanding of coastal risk governance and to assess the degree to which climate change — as a relatively new issue — is integrated in planning systems in our setting. The case study focuses on the Catalan coast (Northwestern Mediterranean Basin) and how the interactions of statutory authorities within policy networks in the European context can hinder or promote ICZM. This focus on the role of formal stakeholders is key to decision-making power and planning integration especially at the regional and national scale (Fisher, 2017). Governmental actors are more stable and easy to define which contrasts with a previous research on the role of informal relationships of statutory and non-statutory authorities, where the boundaries and the characteristics of the networks were more diffuse and unstable but resulted relevant at the local level (Roca et al., 2014).

Multiple risks already converge in the Catalan coast (primarily beach erosion, flooding and marine pollution) and many studies suggest (Guillen, 2008; Jiménez et al., 2012) that the associated risk may be seriously aggravated by climate change, which especially affects vulnerable areas like Catalonia, with its deltas and densely populated coastline. Although the main contribution is methodological, the substantive results of our case study would be relevant to any Mediterranean area — and even to tourist areas elsewhere in the world — experiencing similar problems and risks.

2. Case study: The Catalan coast at risk

The Catalan coastline, in the northwestern Mediterranean region, is both ecologically and socially diverse. Nearly 600 km long, it is highly urbanized, given that around 70% of the 7.5 million inhabitants of Catalonia live within a 20-km wide coastal corridor. Infrastructures and artificial beaches occupy around 152 km of the coastline (Guillen, 2008).

Although this coast displays a large variety of coastal morphologies, such as cliffs, bays, deltas and curved and straight beaches, the few natural resources that remain are at risk from human pressures. Tourism, a major economic sector in Catalonia, with a capacity of some 1.4 million beds, is clearly one factor in this pressure.[1]

Natural pressures also affect the coastal fabric, including storm surges and rising sea levels. Erosion and flooding have been identified as two of the most common risks affecting the Catalan coast, as reflected in reports on coastal risk (Guillen, 2008) and climate change (Sánchez-Arcilla et al., 2012). The fact that one third of the Catalan coast (192 km) is undergoing erosion (Bosom and Jimenez, 2011) requires significant management efforts.

Flooding, in particular, is a major natural hazard, although the impact is not the same on every section of the seafront. Different levels of hazards (Fig. 1) have been identified, including areas at high risk (important river mouths and Barcelona), at intermediate risk (highly urbanized areas and sandy coasts) and at low risk (rocky areas).

Climate change forecasts point to an increase in certain risks that will significantly aggravate the situation of the Catalan coast. Of special concern is the fact that erosion is accelerating; it is already directly affecting certain sectors and is even causing the disappearance of the highly vulnerable Delta de l'Ebre (Guillen, 2008; Jiménez et al., 2012). Findings from climate change studies suggest that extreme events, such as severe storms and floods, are likely to become more frequent and to cause material damage and population displacement and to have adverse effects on food production and fresh water availability. Furthermore, tourism, a driving force in local economies in Catalonia, is likely to be greatly impacted by climate change (Sánchez-Arcilla et al., 2012).

Sea level rise is an important — although not the only — indicator of climate change. Interactions with atmospheric processes may lead to variations in surface winds which, in turn, may affect wave configuration. Changes in the characteristics of sea swells and storms also play a key role in determining the coastal impact of climate change. According to studies by Sánchez-Arcilla et al. (2012), by 2100 it is forecast that the Catalan coast will be eroded by about 100 m in the most vulnerable areas (e.g., Delta de l'Ebre in the south) and by around 70 m elsewhere. Since Catalan beaches range between 50 m and 100 m in width, they are consequently very vulnerable to erosion resulting from a combination of rising sea levels and increased duration and severity of sea storms.

Management of coastal risk in Catalonia is therefore a complex matter; not only does its physical diversity require multiple management strategies, there is also a great variety of stakeholders, interventions and interests at stake. Coordinated action by all stakeholders, but mainly led by public authorities and government departments, would enhance prevention policies regarding natural risks in Catalonia. Below we describe a network analysis methodology as a means to examine the structure of Catalan coastal risk management.

3. Methodology

In order to analyse Catalan coastal risk planning, network analysis complemented with qualitative techniques were used. A network, as a representation of the relationships within a system, is formed by a set of vertices (also called nodes) connected by a set of edges (also called links) (Newman, 2010). Multipartite networks were drawn with vertices representing plans, stakeholders and risks, and edges representing interactions among the vertices. Qualitative work was conducted to analyse the content of administrative documents in order to identify plans, stakeholders and risks and the interactions between them; this information was further validated, at the beginning of 2016, by 12 semi-structured face-to-face interviews, lasting 30–60 min, conducted with experts and administration representatives as follow-up to a semi-structured survey. The interviews were recorded and transcribed before

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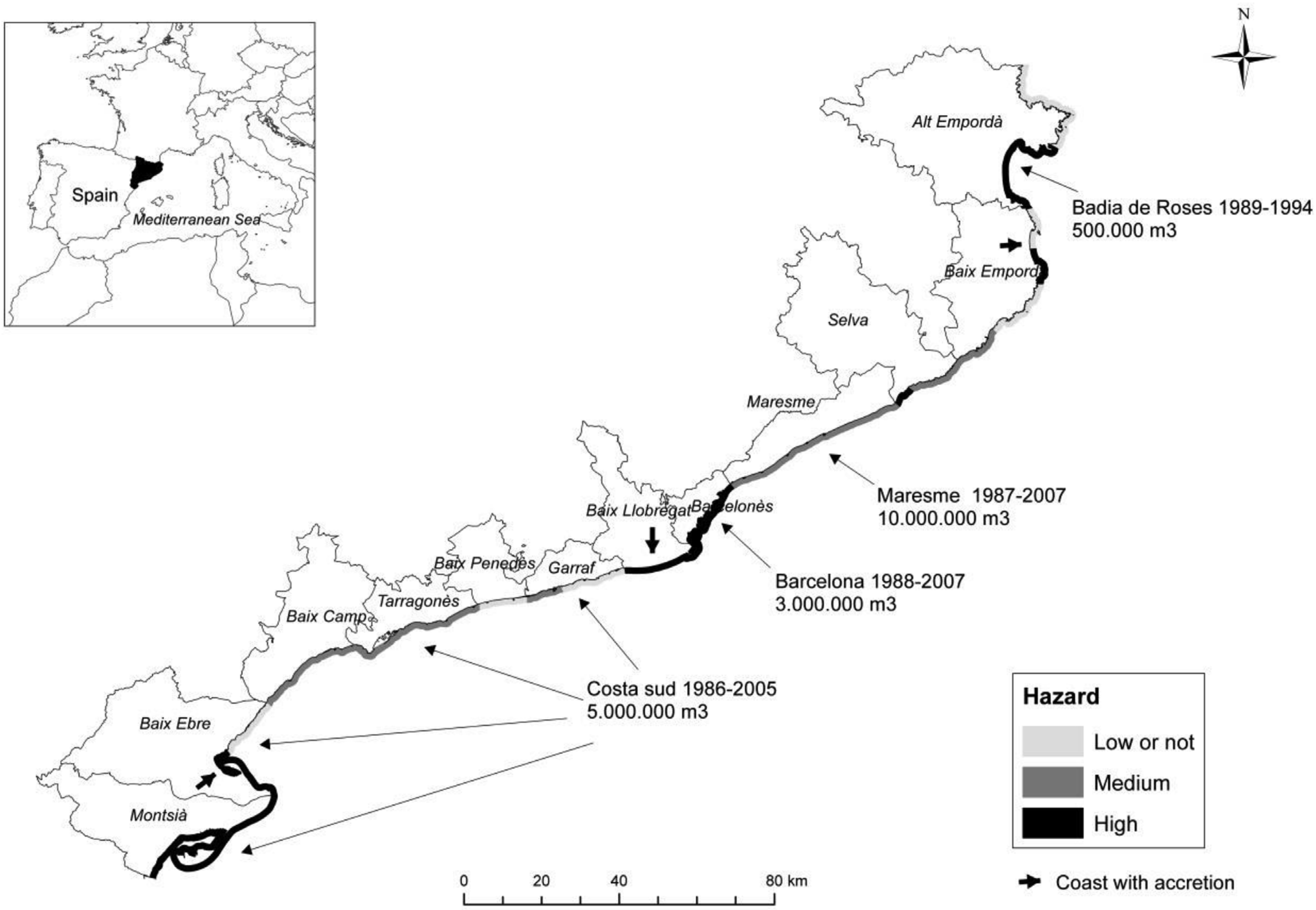

Fig. 1. Catalan coast (NW Mediterranean). Erosion and flood hazard levels and coastal areas with accretion of materials used for artificial beach nourishment.
Source: Adapted from Guillen (2008) by Caridad Ballesteros.

being analysed for content. The information obtained was used to interpret, discuss and provide policy recommendations.

Of the different methods of network analysis, the interest here lies in unipartite projections of bipartite networks (Newman, 2010), also called one-mode and two-mode networks, respectively. Bipartite networks include two kinds of vertices, one representing the original vertices and the other representing the groups to which these belong. The idea behind a unipartite projection is that, given a bipartite network, two original vertices will be connected if they are both connected to the same group (Fig. 2). The result is a clique, i.e., a cluster of vertices in one-mode projections that are all connected to each other.

One-mode projection has the advantage of significantly simplifying the inherent structural complexity of networks containing many different types of nodes. However, in constructing the projection, information present in the structure of the original network is discarded. We partially avoided this problem by introducing weights in the projected network, i.e., giving each edge between two vertices i and j a weight $w_{i,j}$ reflecting the number of groups common to the vertices (Barrat et al., 2004).

Finally, to assess the importance of a node we used weighted degree centrality s_i, also referred to as node strength (Opsahl et al., 2010). Degree k_i — the simplest of the node centrality measures — is defined as the number of edges of a node i. When analysing weighted networks, node strength extends the definition of degree to the sum of the weights of the edges: $s_i = \sum_i k_i w_{i,j}$. This is equivalent to the traditional definition of degree if the network is binary (i.e., each edge has a weight of 1). Conversely, in weighted networks, the outcomes of these two measures are different. Since node strength takes into consideration the weights of the ties, this was the preferred measure for analysing the weighted networks.

One-mode projections of multipartite (usually bipartite) networks have been used to detect particularly significant subgraphs and cliques in networks in several fields, including connections between actors and films (Watts and Strogatz, 1998; Amaral et al., 2000); connections between CEOs and company boards of directors as a way of assessing corporate control (Vitali et al., 2011; Davis et al., 2003); connections by co-authorship, co-citation and bibliographic coupling between papers and authors in different academic fields (Newman, 2001; Barabási et al., 2002); and connections between metabolites and reactions in metabolic networks (Strogatz, 2001) and between proteins and interactions in protein-protein interaction networks (Maslov and Sneppen, 2002).

Three types of nodes were identified in our study:

- **Plans.** Plans implemented before a risk develops were distinguished from plans implemented when a risk had materialized (prevention and emergency plans, respectively). Plans corresponded to three different administrative levels according to the implementer: state, regional (autonomous) government, and local authority.
- **Stakeholders.** Only administrative stakeholders were considered, as the only stakeholders that could be linked to planning within the network (socioeconomic and environmental stakeholders were therefore excluded in this research phase). These stakeholders play diverse management roles, with involvement differing significantly due to several factors. Stakeholders participate in either prevention planning or emergency planning or both.

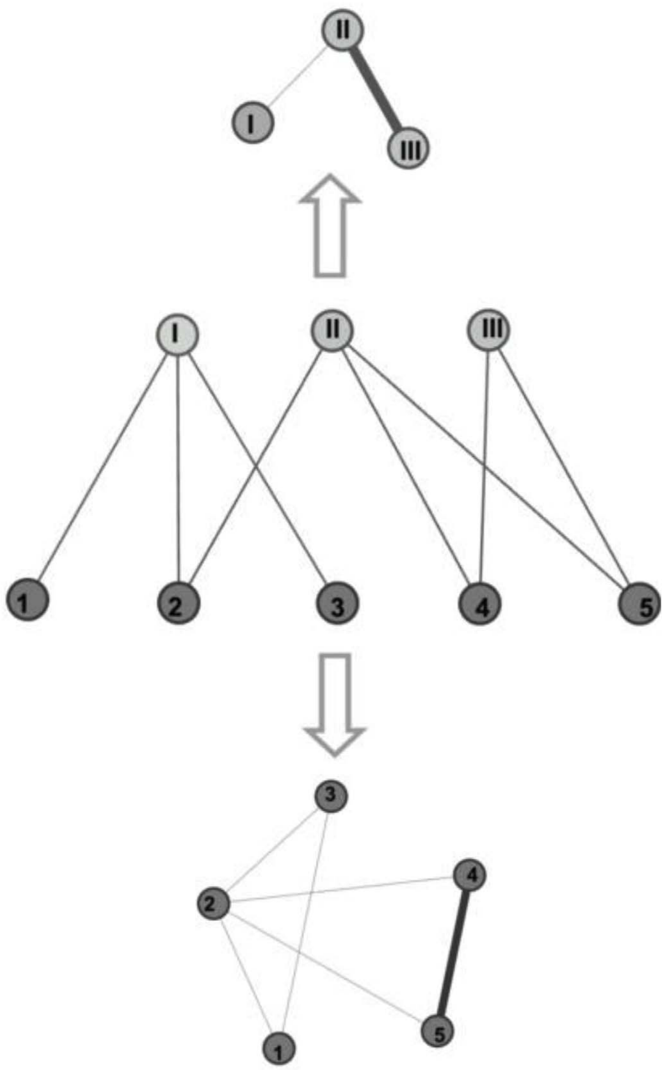

Fig. 2. Example of a bipartite network and its projections.

- **Risks.** Five environmental risks for the Catalan coast were identified by interviewees from a list of natural and man-made hazards: climate change, erosion, flooding, coastal and marine pollution, and sea storms. The limits between them are not always clear, however, as sea storms and flooding can aggravate chronic erosion and climate change has a knock-on effect on other potential hazards. While fully aware that climate change is an aggravating factor for the four other threats to the coast, we classified it as a separate risk so that we could examine to what extent it was integrated in coastal risk planning.

In the corresponding multipartite network, plans, stakeholders and risks were represented as nodes, while the links between them were represented as edges. Given the three-mode definition of the elements, the resulting network was a tripartite graph, and connections were only possible between the vertices of different groups.

The main interest was to examine how plans related to each other in terms of risk management and how stakeholders interacted to manage an emergency or prevention plan. Of the six possible projections, therefore, network analysis here focuses on the following two pairs:

- **Plans-Stakeholders.** Two plans are connected if at least one stakeholder participates in both plans and the strength of this relationship is proportional to the number of stakeholders shared by the two plans. Stakeholders are the real communication link as they need to work together in risk prevention and emergency phases. It would therefore be reasonable to consider that more shareholders mean greater connectedness and less overlapping.
- **Stakeholders-Plans.** This is the inverse situation of plans-stakeholders. Because stakeholders participating in the same plans have to work together, good coordination is fundamental. Thus, the number and type of plans shared between stakeholders determine their closeness or distance in coastal risk planning terms.

4. Results

4.1. Catalan coastal planning

Catalan coastal planning divides risk management into three stages: prediction, planning and recovery. Our focus was the planning phase, as summarized in Table 1, consisting of planning regarding prevention and planning regarding emergencies. In prevention planning, natural risks are integrated into urban planning by delimiting risky areas and by developing and implementing sectoral territorial plans aimed at removing or minimizing these risks. Emergency planning, on the other hand, is reactive and aimed at dealing with a real emergency and alleviating the consequences.

As mentioned earlier, planning is developed and implemented at three main levels: central (state government), regional (autonomous government) and local (municipalities). The European legal framework of several directives on coastal risk management is the regulatory

Table 1
Catalan coastal risk management levels, stakeholders and plans (with identifying acronyms).

Level	Stakeholder	Prevention	Emergency
Spain (central)	General Coastal Directorate (DGC)	Coastal Law (LC) Marine Strategy (EMar)	Ribera Plan (PRIBE)
	Spanish Climate Change Office (OECC)	Strategy for Coastal Adaptation to Climate Change (PNACC)	
	Ebro River Hydrological Confederation (CHE)	Ebro River Hydrological Plan (PHE)	
	Harbour Authority (AUTP)	Plan for General Interest Port Uses (UPORTE)	
Catalonia (regional)	General Land Use Planning Directorate (DGOTU) General Ports Directorate (DGPORTS) Catalan Water Agency (ACA) Catalan Climate Change Office (OCC) Civil Protection (PROTCIVIL)	Territorial Plans (TERRIT) Catalan Ports Plan (PORTS) Management Plan for Catalan Drainage Basins (PGDCFC) Catalan Strategy for Adaptation to Climate Change (ESCACC)	Civil Protection Plan (PROCICAT) Marine Pollution Plan (CAMCAT) Flooding Plan (INUNCAT)
Local (municipalities)	Town/city councils (AJUNTAMENT)	Municipal Urban Planning Instruments (POUM)	Emergency Municipal Civil Protection Plans (PAEM) Municipal Intervention Plans (PAM) Specific Municipal Plans (PEM)
	Private activity (PARTICULAR)		Self-Protection Plans (PAUT)

umbrella for the following plans:

- **Central** (the Spanish state). The main tools for planning (either recently developed or in the development phase) are the Law for Protection and Sustainable Use of the Coast and the Law on Modification of the Coast (Coastal Law; LC), the Marine Strategy for the Eastern-Balearic Marine Area (EMar), the State Plan for Protection of the Marine Environment Against Pollution (Ribera Plan; PRIBE) and the Strategy for Coastal Adaptation to Climate Change, all the responsibility of the General Coastal Directorate (DGC) attached to the Spanish Ministry of Agriculture, Food and the Environment. The LC and the PRIBE both integrate prevention and emergency regarding the risks they manage: the former protecting the marine-terrestrial public domain from the effects of storms, sea level rises and erosion, and the latter concerned with environmental quality and marine and coastal pollution.
- **Regional** (the Catalan Autonomous Government). Responsibility for prevention and emergency management is fragmented: emergency planning falls under Civil Protection, responsible for the Civil Protection Plan (PROCICAT), the Marine Pollution Plan (CAMCAT) and the Flooding Plan (INUNCAT). Spatial planning is via Territorial Plans (TERRIT), the responsibility of the General Land Use Planning Directorate (DGOTU).
- **Local** (municipalities). Prevention plans, which are developed by town/city councils (AJUNTAMENT) through urban planning instruments (POUM), play a key role in emergency management.

Specific planning to take account of climate change as an aggravating coastal risk factor has commenced at the state and regional level, focusing on the time frame 2013–2020. This planning takes the form of the Spanish Strategy for Coastal Adaptation to Climate Change (PNACC), the responsibility of the Climate Change Office attached to the Spanish Ministry of Agriculture, Food and the Environment (OECC), and the Catalan Strategy for Adaptation to Climate Change (ESCACC), the responsibility of the Catalan Climate Change Office (OCC).

4.2. Network analysis

A first approach to analysing risk planning is to understand how risk management stakeholders relate to each other. Using one-mode projections, a network is defined when two stakeholders are connected because they deal with a common risk. This reveals how connected entities work along the same lines. We are aware that there is no guarantee that they are well coordinated, which is why qualitative research is necessary to explore in depth the type of relationships established.

Coastal risk governance in Catalonia involves a network of 13 stakeholders (Fig. 3) dealing with five types of risks (as mentioned earlier): erosion, flooding, coastal and marine pollution, sea storms and climate change. It can be observed that the network is very dense. The density ρ of a network is defined as the ratio between the number of edges m and the maximum possible number of edges m_{max}, which, in a network with n nodes, is $m_{max} = n(n-1)$. A fully connected network is $\rho = 1.0$. In our case, $\rho = 0.91$, which indicates that nearly all stakeholders share the management of at least one risk with other shareholders. The fact that our network is not fully connected is because some stakeholders focus their efforts on a single risk – the case of the Catalan Climate Change Office (OCC) and the Spanish General Directorate for Fishing and Maritime Affairs (DGPESCA), which focus, as their names would indicate, on climate change and marine pollution, respectively. There are seven pairs of stakeholders that do not share the management of any risk. The full network of stakeholders reflects the complexity and interconnectivity between the risks and their management.

Fig. 4 is the same network as depicted in Fig. 3, but filtered according to a weighting system that highlights stakeholders managing three or four risks in common (no pair of stakeholders share management of all five risks). Since all 13 stakeholders have similar concerns, their connectedness in reality should be stronger. Five stakeholders feature in two strongly connected subsets of the network. Thus, the first subset consists of the triad formed by the General Coastal Directorate (DGC), the Ebro River Hydrographical Confederation (CHE) and the Catalan Water Agency (ACA), all involved in planning focused on flooding, erosion, coastal and marine pollution and climate change. The strong interconnectivity between these three stakeholders is partly explained by the fact that hydrological plans are the only territorial sectoral plans with a genuinely holistic objective of reflecting all dynamics affecting a territory in a single plan. As for the second subset, this consists of the pair formed by town/city councils (AJUNTAMENT) and Catalan Civil Protection (PROTCIVIL), involved in the management of emergency-phase coastal risk, which incorporates risk associated with erosion, flooding, sea storms and coastal and marine pollution (but not climate change).

Leaving aside this general overview of the coastal risk planning system, another perspective is to study relationships between stakeholders dealing with a specific risk — in other words, the connectedness between stakeholders involved in planning for a specific risk.

- **Erosion** (Fig. 5). Of the initial 13 stakeholders, ten deal with erosion risk. It can be observed that three stakeholders are centrally positioned in coastal erosion management, as evidenced by links

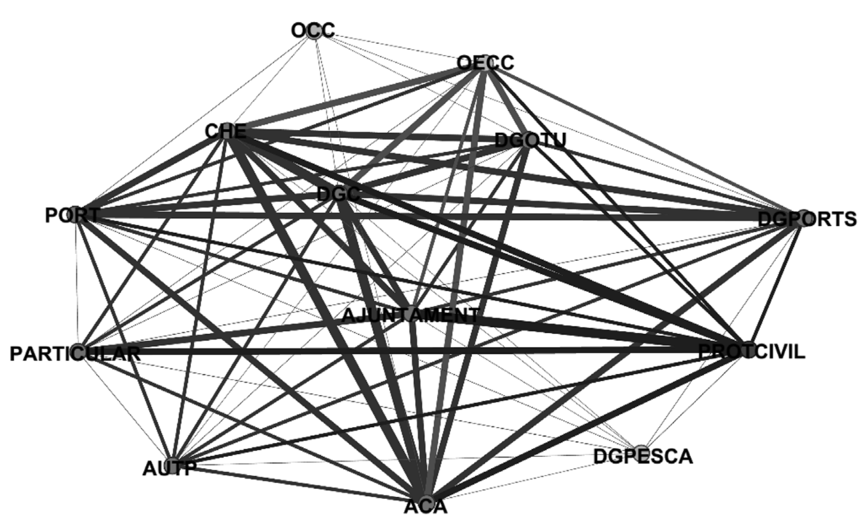

Fig. 3. Network of 13 stakeholders involved in coastal risk governance (erosion, flooding, coastal and marine pollution, sea storms and climate change).

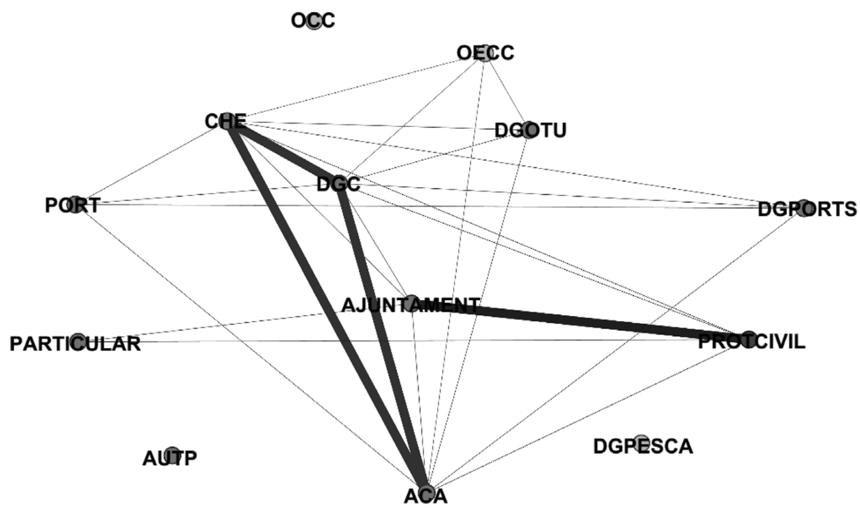

Fig. 4. Filtered network of 13 stakeholders managing three or four risks.

between the General Coastal Directorate (DGC), town/city councils (AJUNTAMENT) and the Catalan Land Use Planning Directorate (DGOTU). The involvement of several stakeholders in erosion risk planning would suggest that this risk is growing. Erosion is part of emergency planning, as evidenced by the participation of Civil Protection (PROTCIVIL), but is also part of prevention planning, as indicated by both the involvement of the Catalan Land Use Planning Directorate (DGOTU) and the inclusion of this coastal risk factor in spatial and urban planning. Climate change is also considered in relation to erosion, as indicated by the participation of the Spanish Climate Change Office (OECC). Nevertheless, those connections are weak, with four stakeholders — the Catalan Water Agency (ACA), the Harbour Authority (AUTP), the Ebro River Hydrographical Confederation (CHE) and the General Ports Directorate (DGPORTS) — only taking part in one plan each. Finally, the General Coastal Directorate (DGC) — connected as it is to most of the stakeholders — is involved in almost all plans related to erosion. In reality, the General Coastal Directorate (DGC) concentrates both competences and decision-making capacity, leaving the remaining stakeholders with little or no decision-making power.

- **Flooding** (Fig. 6). Although the network consists of nearly the same set of stakeholders as in the erosion network, its structure is significantly different. Here the strongest links are between a group formed of town/city councils (AJUNTAMENT), the Catalan Land Use Planning Directorate (DGOTU), Civil Protection (PROTCIVIL) and the Catalan Water Agency (ACA). Cross-management of flooding risk can be observed, with Civil Protection (PROTCIVIL) — for emergency planning — and the Catalan Land Use Planning Directorate (DGOTU) — for prevention planning — occupying central positions (recall that we define centrality as the weighted degree centrality, also known as node strength (Opsahl et al., 2010)).

Comparing Fig. 6 (flooding) with Fig. 5 (erosion), the fact that the former has more edges — $w_{i,j} > 1$ — denotes that flooding risk management is not focused on a central stakeholder but is distributed among several bodies, which would suggest balanced risk between phases and administrative levels.

- **Climate change** (Fig. 7). The fact that climate change does not reflect the emergency perspective of Civil Protection (PROTCIVIL), town/city councils (AJUNTAMENT) or a private entity (PARTICULAR) would point to a broader view of this issue. Currently, all plans dealing with climate change reflect the prevention phase, so the nine stakeholders are connected through these plans — although some also take part in emergency planning for other coastal risks. The link between the Spanish Climate Change Office (OECC) and the General Coastal Directorate (DGC) is maximally weighted. As a state-level body, the Spanish Climate Change Office (OECC) is more powerful than the Catalan Climate Change Office (OCC); the latter plays a peripheral role (as illustrated in the figures), mainly focusing

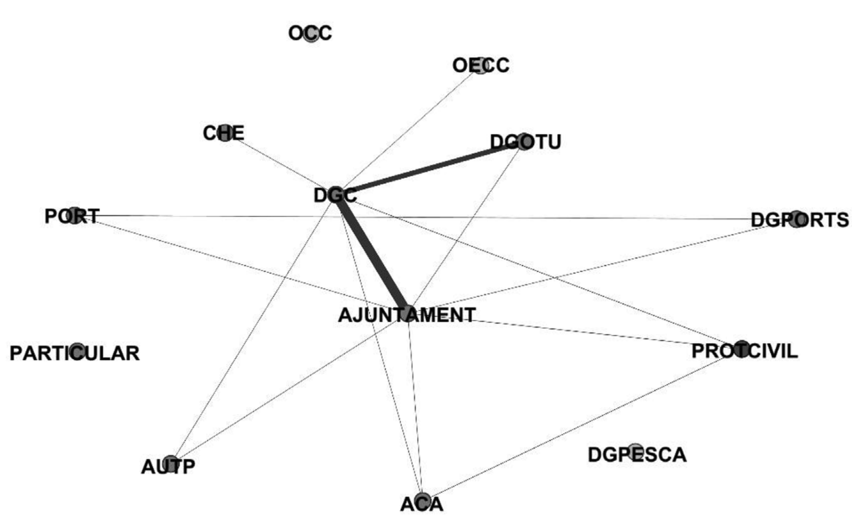

Fig. 5. Network of stakeholders connected through coastal erosion plans.

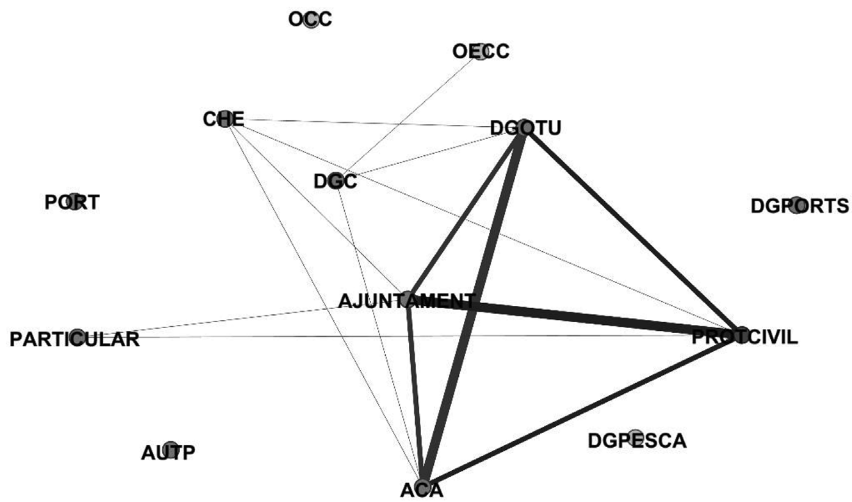

Fig. 6. Network of stakeholders connected through flood risk plans.

on Strategic Impact Assessment procedures. Therefore, integration of climate change into coastal risk planning is far from ideal. While governance of this complex issue is currently the responsibility of the OECC, the OCC and the DGC, coordination with bodies dealing with other risks seems to be poor. Climate change needs to be explicitly included in sectoral policies. Pending climate change legislation (still in a preliminary draft phase) is expected not only to place OCC in a position to more usefully influence planning phases, but also to include climate change as a factor in other policies.

A second — complementary — approach to analysing coastal risk planning is through relationships between plans in terms of common stakeholders: thus, two plans are related if a particular stakeholder is involved in both. The weight of a connection (i.e., an edge) between two nodes in a network represents the number of common stakeholders. Denser networks with higher edge weights point to more consolidated relationships and, consequently, more coordinated interventions.

In our study, coastal risk networks for Catalonia were generated with a view to analysing the connectivity of plans dealing with the same three risks as analysed above: erosion, flood risk and climate change. Seven plans deal with erosion (Fig. 8), mainly hydrological and harbour plans, and with plans for risk prevention. Although the original network is very dense, it cannot be said that the governance of erosion is decentralized. Since the General Coastal Directorate (DGC) is linked to most other stakeholders dealing with erosion (Fig. 5), this would suggest that most of the connections between plans depicted in Fig. 8 are the result of the presence of the DGC — which would indicate no decentralization of erosion management. The Coastal Law (LC), in fact, governs the rest of plans and therefore is positioned at the top of the erosion governance hierarchy.

Regarding flooding (Fig. 9) — and bearing in mind its complementary network (Fig. 6) — we observe risk cross-management in both emergency and prevention planning. This is because, first, the mitigation of possible damage would require an immediate reaction by institutions, and second, flooding risk is beginning to feature in urban planning (e.g., bans on certain kinds of construction in flood-risk areas). The local scale is represented in both planning phases, through Municipal Urban Planning Instruments (POUM) for prevention, and through the other municipal plans (PAM, PAEM and PAUT) for emergencies. Concerning the network structure, a subset of four plans represent the main link between all the flood risk plans: the Management Plan for Catalan Drainage Basins (PGDCFC), the Ebro River Hydrological Plan (PHE), the Flooding Plan (INUNCAT) and the Territorial Plans (TERRIT). Stakeholders taking part in this planning are more diverse, including as they do, different administrative levels (central, regional and local) and different planning phases (prevention and emergency). Since connections are not through a single main body, as happens with the General Coastal Directorate (DGC) for erosion, this would indicate

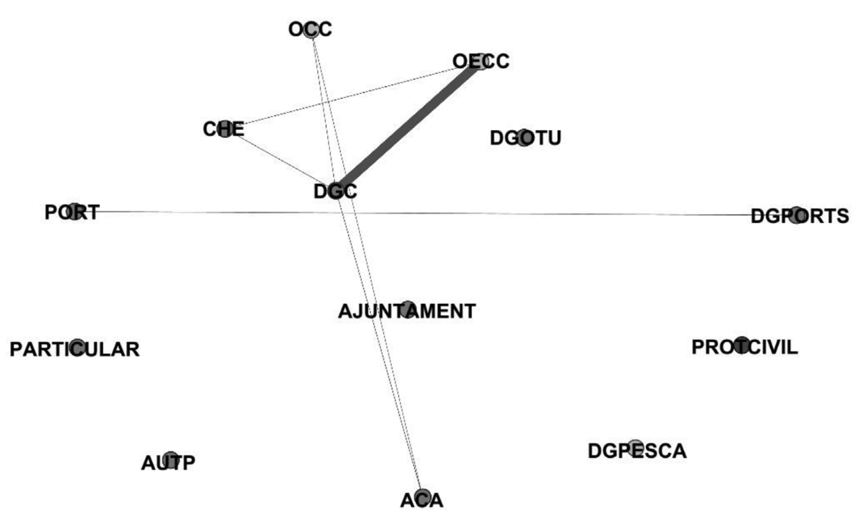

Fig. 7. Network of stakeholders connected through climate change plans.

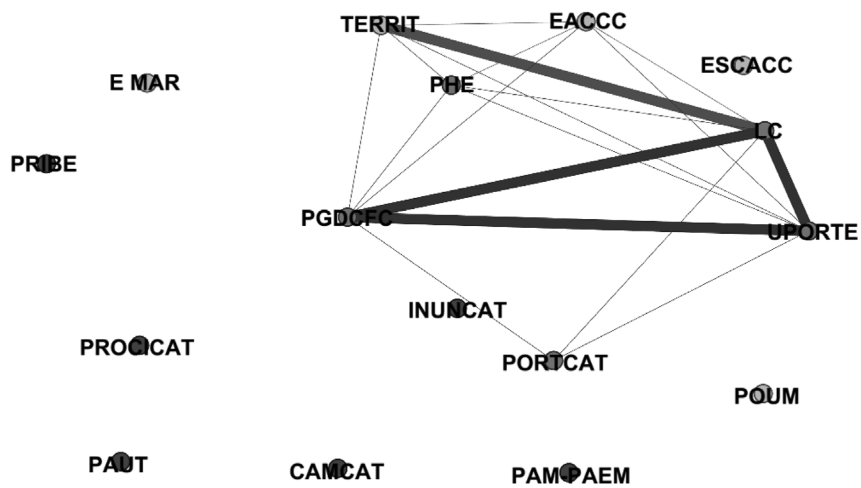

Fig. 8. Network of plans connected by erosion management stakeholders.

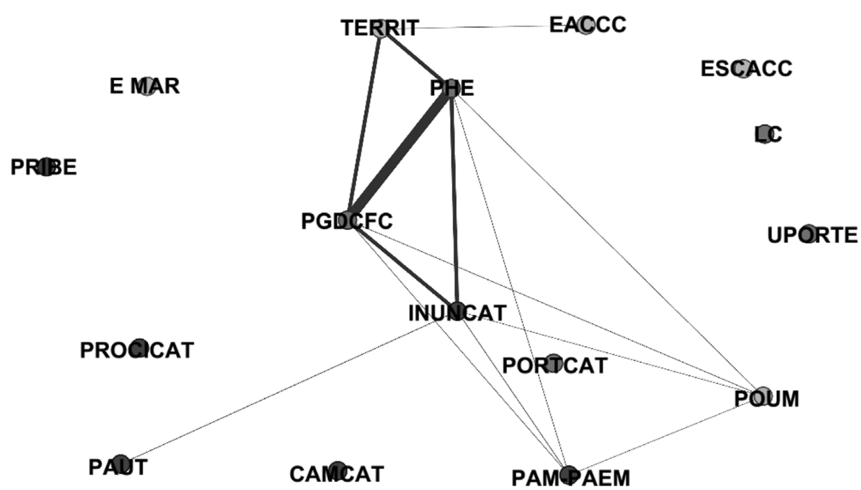

Fig. 9. Network of plans connected by flood risk management stakeholders.

that coordination between these plans is more decentralized.

The final risk considered is climate change (Fig. 10), which, although it has a negative impact on the other four natural hazards mentioned above, has only recently come to be considered as a significant hazard in its own right.

Noteworthy is the well-connected triad formed by the Coastal Law (LC), the Ebro river Hydrological Plan (PHE) and the Spanish Strategy for Coastal Adaptation to Climate Change (PNACC), which have the General Coastal Directorate (DGC) and the Spanish Climate Change Office (OECC) as the main common stakeholders. Although hydrological plans typically recognize the existence and consequences of climate change, their reliability — and therefore, confidence in them —

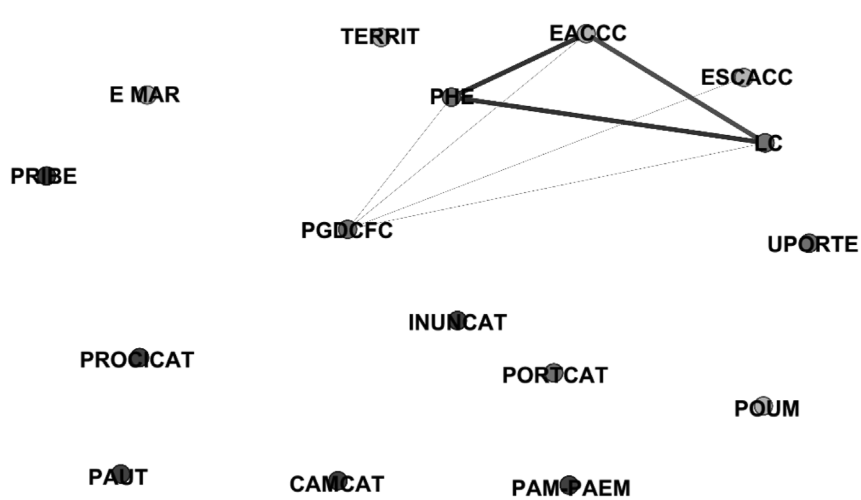

Fig. 10. Network of plans connected by climate change management stakeholders.

are low when phenomena are quantified only in terms of regional and local impacts. At the regional level, therefore, the Catalan Strategy for Adaptation to Climate Change (ESCACC) seems to be rather disconnected, with the Catalan Climate Change Office (OCC) as the only stakeholder driving a climate change strategy. There is no explicit mention of the coast as such, only of economic sectors that have an impact on the coast (such as tourism, agriculture and fishing) and plans and operational tools to deal with these impacts are still lacking.

It is expected, nonetheless, that new climate change legislation currently being drafted will lead to new management tools that more explicitly integrate climate change into planning.

5. Discussion

The use of one-mode (unipartite) projections regarding coastal risk planning for Catalonia provides information that is consistent with a qualitative analysis based on key stakeholder interviews (Roca and Villares, 2016). The main contributions of this research are two. First, the case study provides substantive network analysis results — regarding coordination among stakeholders, centralization of risk management power, management phase integration and a multi-risk approach to planning — that are complemented by the qualitative information from the in-depth interviews, especially in regard to policy recommendations. Second, our research makes a methodological contribution to network analysis in terms of its strengths and limitations.

Planning in the emergency phase is well coordinated. Civil Protection performs a key role by activating suitable plans for specific risks (mainly, PROCICAT for civil protection, INUNCAT for flooding and CAMCAT for pollution) and by mobilizing and coordinating stakeholders (such as the town/city councils or potentially affected private entities). This also has the result of inspiring a high degree of appreciation and confidence in local stakeholders, as has been pointed out by those experiencing the consequences of natural coastal risks first-hand (municipalities, associations, etc.).

In contrast, planning in the prevention phase is rather unfocused and lacks overall integration of coastal risks in spatial and urban planning — an issue that has been illustrated in both the network analysis and the in-depth interviews. An integrated approach to creating coordination mechanisms is therefore needed. An overall risk perspective only exists for water management planning, due to water and flood directives. Coastal erosion risk management requires further strategic instruments that would replace the current highly centralized governance system and ensure the participation of the full range of stakeholders. As several stakeholders have suggested, the Catalan coastal plan that is currently being drawn up at the regional level could bridge this gap.

There is also an obvious lack of connectedness between prevention planning and emergency planning. Integrating both phases would represent a step forward towards a broader holistic approach and would, consequently, fulfil one of the guidelines of ICZM regarding more unified management of coastal areas. As a means to enhance ICZM, one option — proposed by Catalan authorities and academia (Pahl-Wostl, 2009) — would be to decentralize competencies and responsibilities to independent but coordinated governance groups. Such a system would avoid focusing all risk management in one or a few stakeholders and would ensure better adaptation to a changing environment through shared responsibilities. Diversifying would also ensure a more equitable distribution of power (Bodin and Crona, 2009). Stojanovic and Ballinger (2009) propose the creation of bridging and participatory organizations — for instance, coastal partnerships — that could function to promote dialogue and communication between different stakeholders; this issue was also highlighted in an interview with a regional representative of the Catalan Climate Change Office.

Many interviewees — corroborating the international literature — claim that the gradual degradation of coastal areas urgently requires improved integration and coordination, especially now that climate change is further aggravating risk events and their consequences. A combination of both mitigation and adaptation strategies are essential to developing suitable responses. Traditionally, adaptation was viewed as the competency of national governments and was implemented through national mechanisms, such as national adaptation programmes. However, interviewees from the Regional government and the Catalan Water Agency (ACA) suggest that the local level should be involved with all cross-level stakeholders. As Flannery et al. (2015) point out, to reduce the vulnerability of coastal populations, risk adaption strategies need to be built into local spatial planning processes, yet local government entities operate within a complex hierarchical governance framework and, consequently, tend to be constrained by higher level plans, policies and legislation. Overcoming this weak integration of climate change in statutory planning requires — as pointed out by the) Climate Change Catalan Office — greater political awareness and standardized assessment methodologies and operational tools to implement programmes and actions.

At the methodological level, the use of network analysis as a complementary tool to qualitative analysis has both strengths and weaknesses. Nonetheless, the use of simple weighted edges (rather than non-weighted edges) in a one-mode projection, as in our case, enabled more information to be captured than would have been the case for the original bipartite graph, as the intensity of connections between two nodes, as depicted by weighting edges, clearly indicates stronger and weaker relationships.

The most obvious strength of one-mode projections, and networks in general, is their potential as a visualization tool to support qualitative analyses. The use of different colours and sizes for nodes, as well as filters by weight for edges, are complementary features that enhance network analysis outcomes.

An obvious and significant weakness is that unipartite networks imply an important loss of information, since the construction of one-mode projections results in much of the information in the original bipartite network being discarded, resulting, therefore, in a less powerful representation of the data. Moreover, hierarchies of plans and stakeholders cannot be drawn up since the initial database is a simplified representation designed to enable working with networks.

However, the information resulting from qualitative techniques provides material for understanding and interpreting the information content of networks. The complementarity between quantitative and qualitative perspectives is ultimately useful for dealing with complex issues.

6. Conclusion

Understanding risk planning systems is essential to improving the sustainability of coastal environments. Our main objective was, using network analysis, to shed light on how the current Catalan planning system copes with coastal risks such as erosion, flooding, pollution and sea storms and, at the same time, to assess how climate change is being integrated in this planning system.

Results show the complexity of the legal and administrative framework governing Catalan coastal risk planning, which partly reflects the diversity of causes, origins and temporal and spatial scales that characterize hazards and risks. Our findings point to dissimilar management traditions depending on the type of risk. In the emergency phase, flood risk is mainly managed by local and regional Civil Protection services, which have a more unified, multi-risk perspective. However, they have no responsibility for coastal erosion — a significant component in overall Catalan coastal risk — which is, instead, managed from a higher administrative level.

Climate change, weakly present in current statutory planning in Spain, is only taken into account mainly through Strategic Impact Assessment procedures. More appropriate climate change strategies are therefore still required at the local and regional levels. Hydrological planning — despite being more complex and holistic — reflects climate change as a general issue rather than in any quantitative way. However, upcoming climate change legislation in Catalonia — aimed at adopting a legal consideration of climate change in different sectoral policies — has raised many expectations.

Our research demonstrates the value of network analysis for coastal risk planning in that it illustrates and quantifies the complexity and interconnectedness of stakeholders and plans. Although much network analysis research is still needed to study institutional aspects in different contexts, the outputs will always require a qualitative approach to properly interpret results.

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